Design and Construction of RPC Detectors & a Cosmic Ray Test Stand

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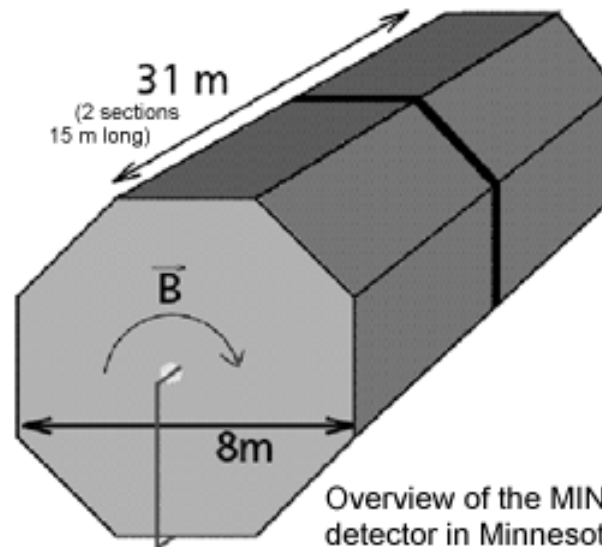
OFF-AXIS EXPERIMENT

- A neutrino oscillation experiment
- Looking for transition of muon neutrinos to electron neutrinos
- Using NUMI Beam
- 50,000 ton of detectors are going to be located slightly OFF of the "MINOS Far Detectors" in Minnesota
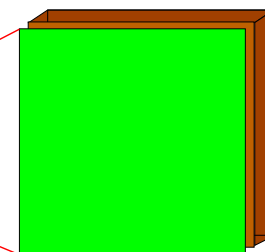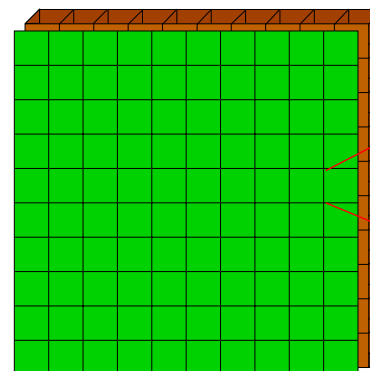- Further exploitation of FNAL investment in NUMI beam production.

Detector Site

MINOS

Overview of the MINOS detector in Minnesota.

31 m (2 sections 15 m long)

$\vec{B}$

8m

Absorber + detector wall stacked in a LEGO–like fashion from fundamental blocks

OFF-AXIS

2x2x0.25 m absorber block (fused pellets or filled box) supporting RPC chamber

Soudan

Minn.

Wis.

Fermilab

Ill.

Choice of Detectors Calorimeter

Two Sub-Groups of the OFF-AXIS experiment are doing R & D on two different detector calorimeter for the proposed 50,000 ton Detector:-

◆ Scintillators

◆ Resistive Plate Chambers(RPCs)

Project

I work within a sub-group of the OFF-AXIS group and I participated in the following R &D for RPCs:-

- Design and construction of prototype RPCs
- Design and construction of a cosmic ray experimental test stand
- Other small projects (acceptance calculations, glue joint strength test,..)
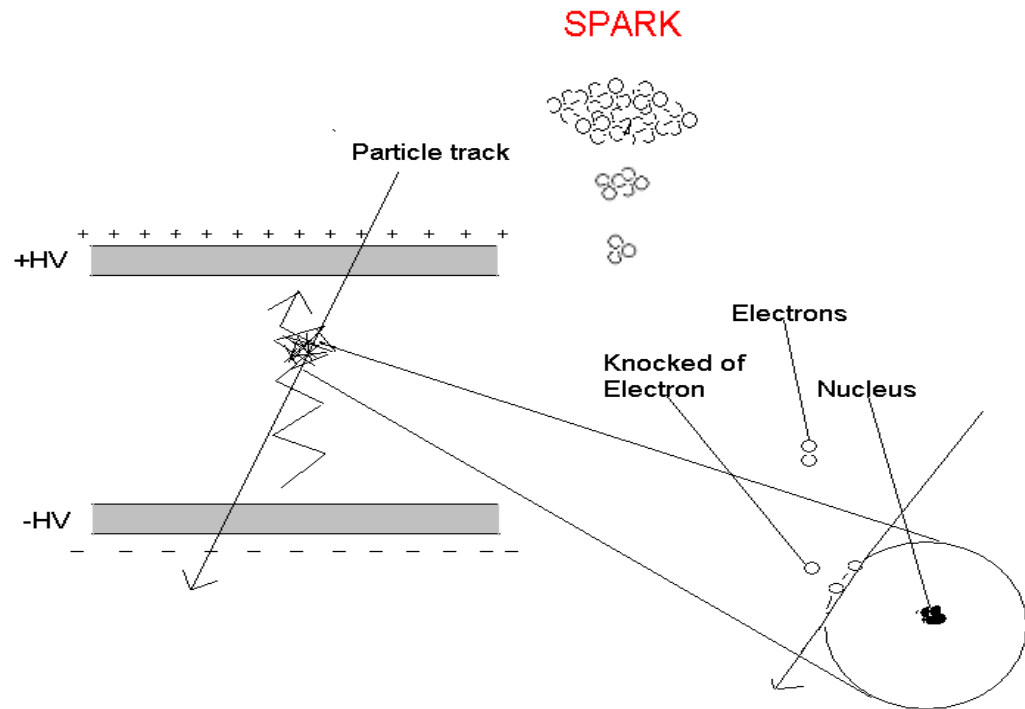
Principles of Operation of Glass RPC

Signal pickup (x)

Glass plates

Signal pickup (y)

Resistive paint

8 kV

Resistive paint

Spacers
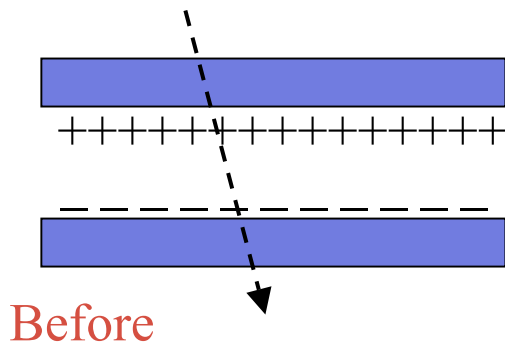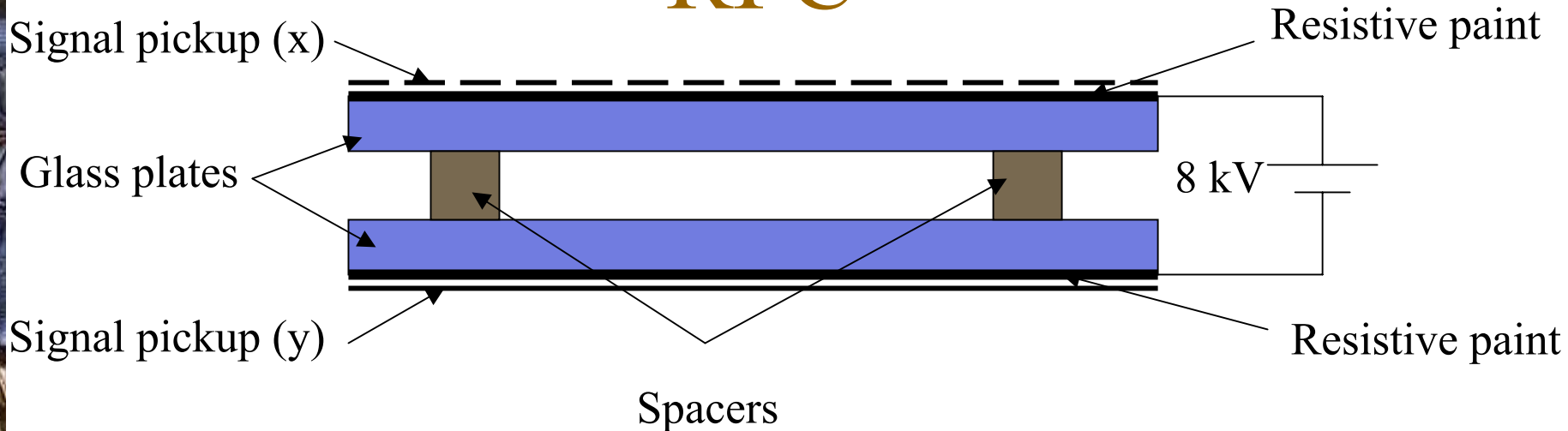
A passing charged particle induces an avalanche, which develops into a spark. The discharge is quenched by a quencher gas.

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Before
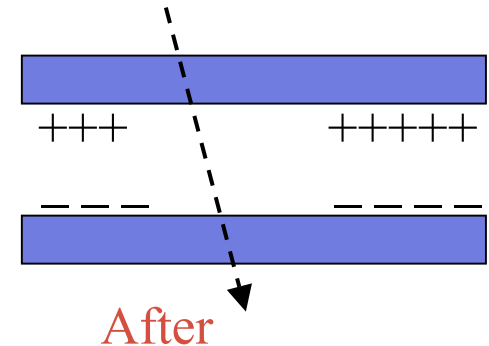
The discharged area recharges slowly through the high-resistivity glass plates.

+++   +++++

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After

RPCs Components

SPARK

Particle track

+ + + + + + + + + + + + +

+HV

-HV

Electrons

Knocked of
Electron

Nucleus

◆ Gas Mixture:
 – Argon(Ionization Gas)
 – Isobutane(Quencher Gas)
 – Freon(Quencher Booster)
◆ HV: 8KV-9KV for electric field
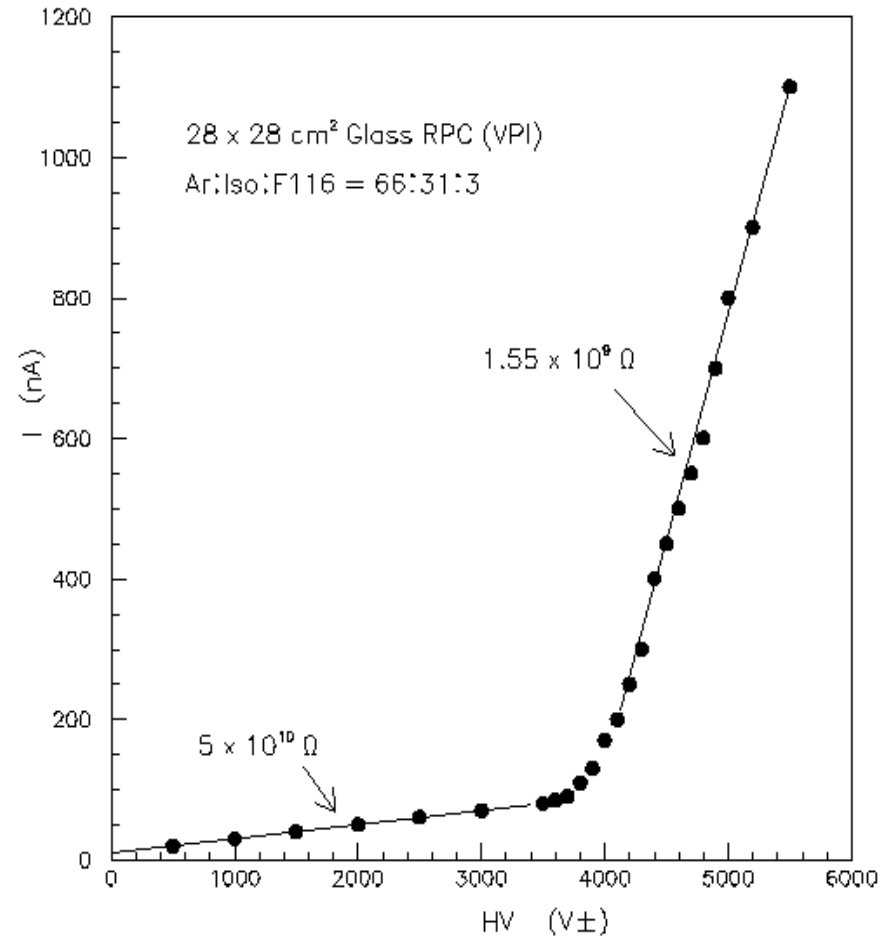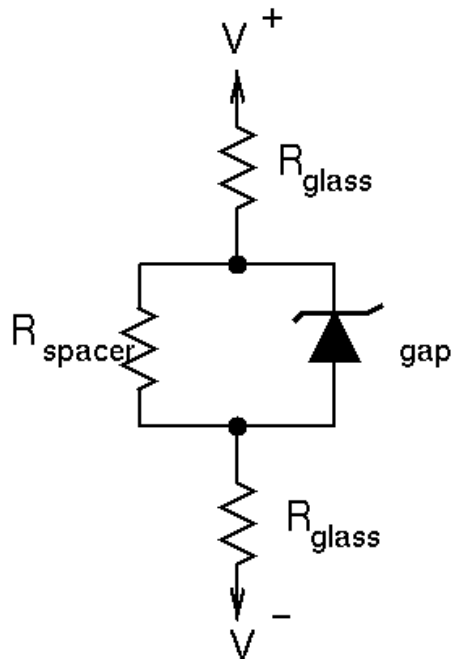◆ Electrodes: Define electric field volume

Equivalent Circuit of RPCs

- Low voltage

  - $R_{gap} \approx \infty$
  - $\dfrac{dV}{dI} = R_{spacer}$

- High voltage

  - $R_{gap} \approx 0$
  - $\dfrac{dV}{dI} = R_{glass}$

28 x 28 cm^2 Glass RPC (VPI)

Ar:Iso:F116 = 66:31:3

$1.55 \times 10^9 \ \Omega$

$5 \times 10^{10} \ \Omega$

Well understood I vs V relationship

Why RPCs ?

- RPCs are **extensively** use in Astrophysics and High Energy Physics.
- Very **cheap** compared to other options
- Very **large** signal
- A **good** time resolution
- **Excellent** and **cheap** readout system
- They are very **simple** devices

What are the Issues?
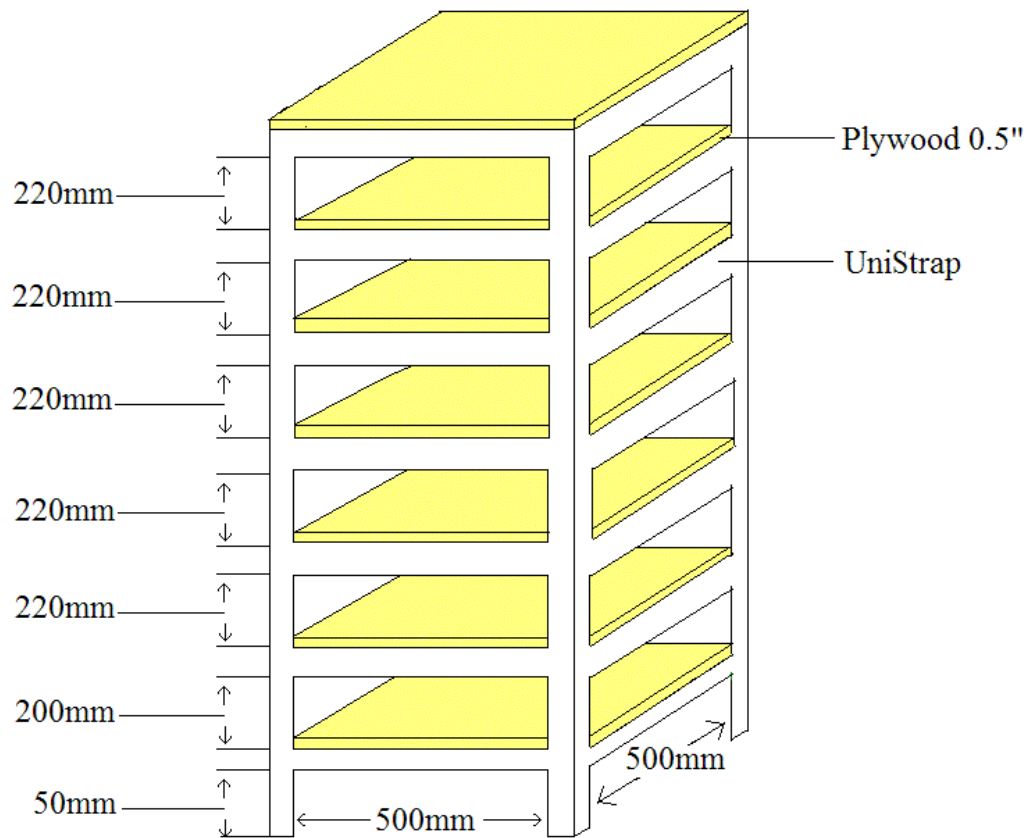
- **Long** term stability ?
- Detection **Efficiency** ?
- RPCs are not built the same way, construction **varies** according to experimental need.
- RPCs assembly is a precision work; for long life **quality control** is essential
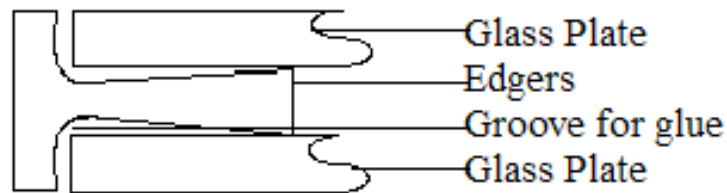
- Test Setup is needed to study these issues

Test Stand Design & Criteria

- Study performance of RPCs under different running conditions (gas flow, temperature, etc)
- Five slots for five groups of RPC to be run in different conditions
- Two slots for two pairs of scintillators
- Scintillators are needed to define the area of RPC for events signals and to give trigger logic
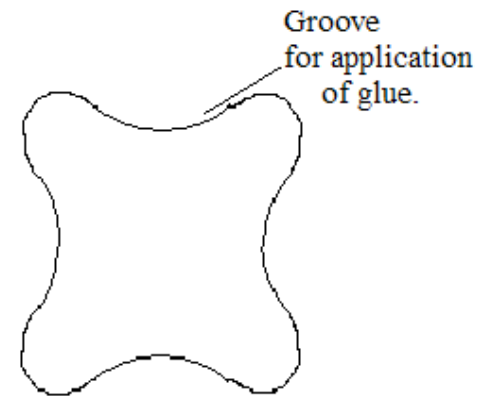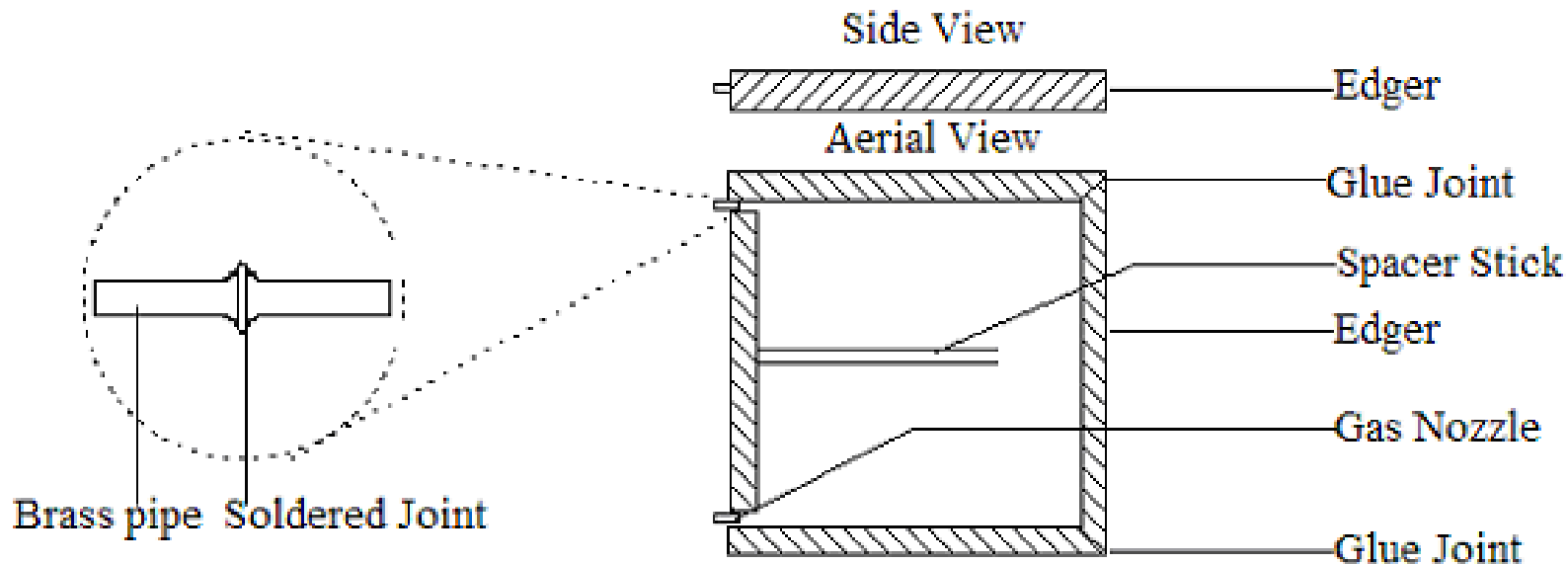- Use cosmic rays as a probe

Test Stand

Plywood 0.5"

UniStrap

220mm

220mm

220mm

220mm

220mm

200mm

50mm

500mm

500mm

Constructed RPC frame

Glass Plate
Edgers
Groove for glue
Glass Plate

Edger to Glass joint.

Groove
for application
of glue.

Spacer cross sectional profile.

Side View

Edger

Aerial View

Glue Joint

Spacer Stick

Edger

Gas Nozzle

Glue Joint

Brass pipe Soldered Joint

gas pipe

Gas pipe

RPC frame

Glass RPCs frame components
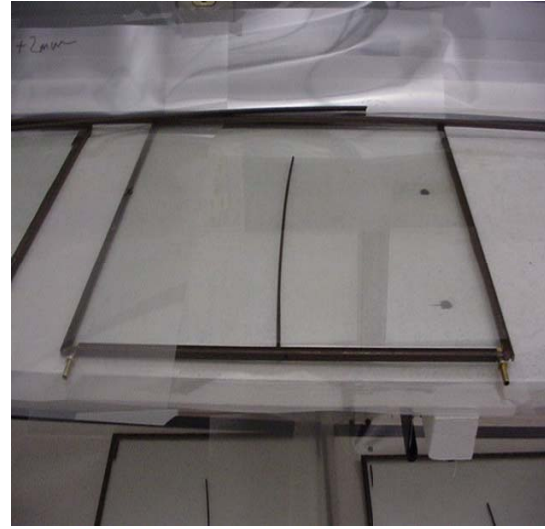
- Two parallel Glass Plates

- Spacers to give a precise distance of 2mm, for uniform electric field between the two glass plates.

- Edgers for sealing the borders of the glass plates and creation of a gas volume

- 3M 2216 translucent epoxy glue.

- Gas Nozzles

High Voltage Supply

Anode

Gas Inlet

Cathode

Gas Outlet

Ground
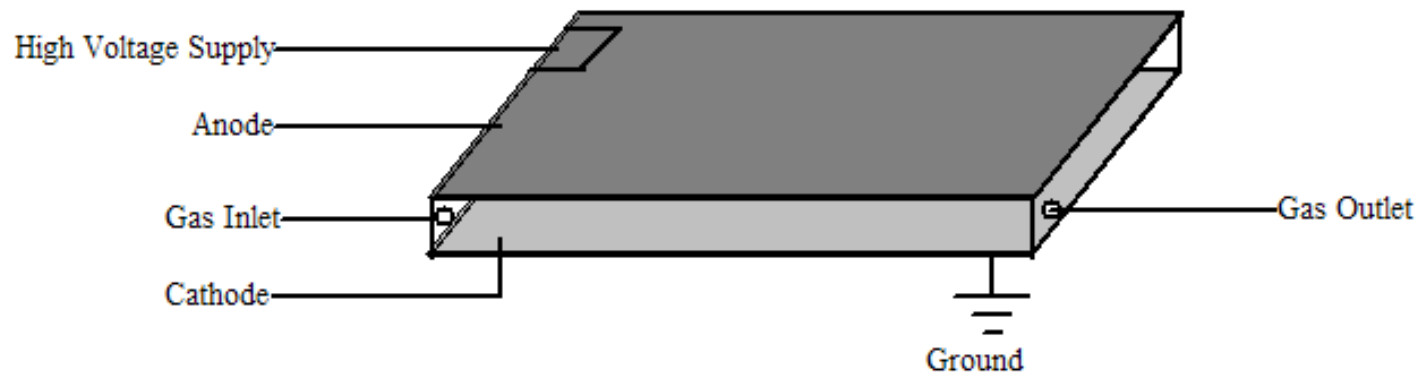
RPC frames and Gas Nozzle
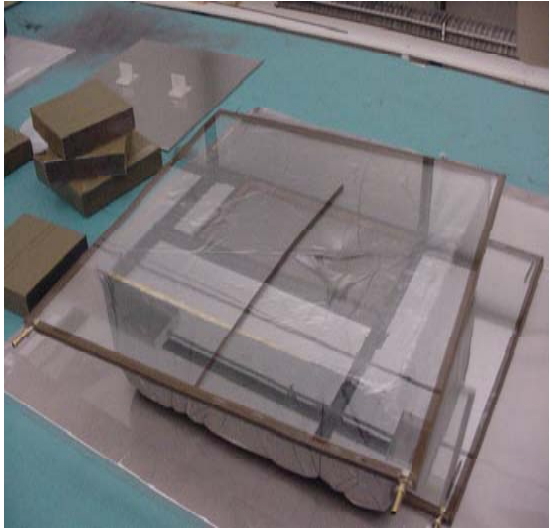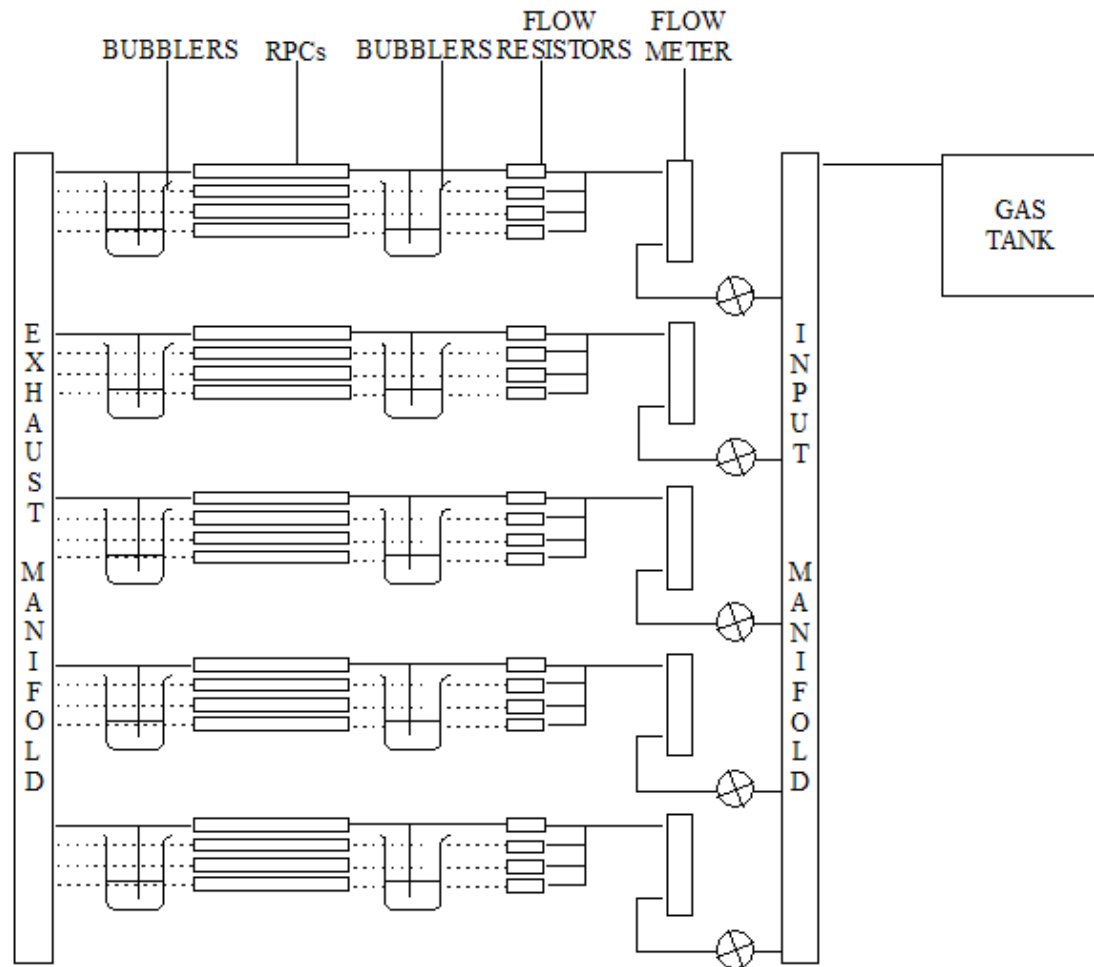

RPC frame

RPC frame

Gas nozzles fitted to the frame

Gas Nozzles

Design of Gas System

Gas System Components

- Bubblers: For balancing changes in atmospheric pressure exerted on RPCs

- Flowmeter: A gauge meter that measures the rate of a gas flow

- Flow Resistor: A 200μm tube that takes away pressure from the RPC

- Manifolds: For intake and outtake of gas.

Design of panel for fitting of gas system components
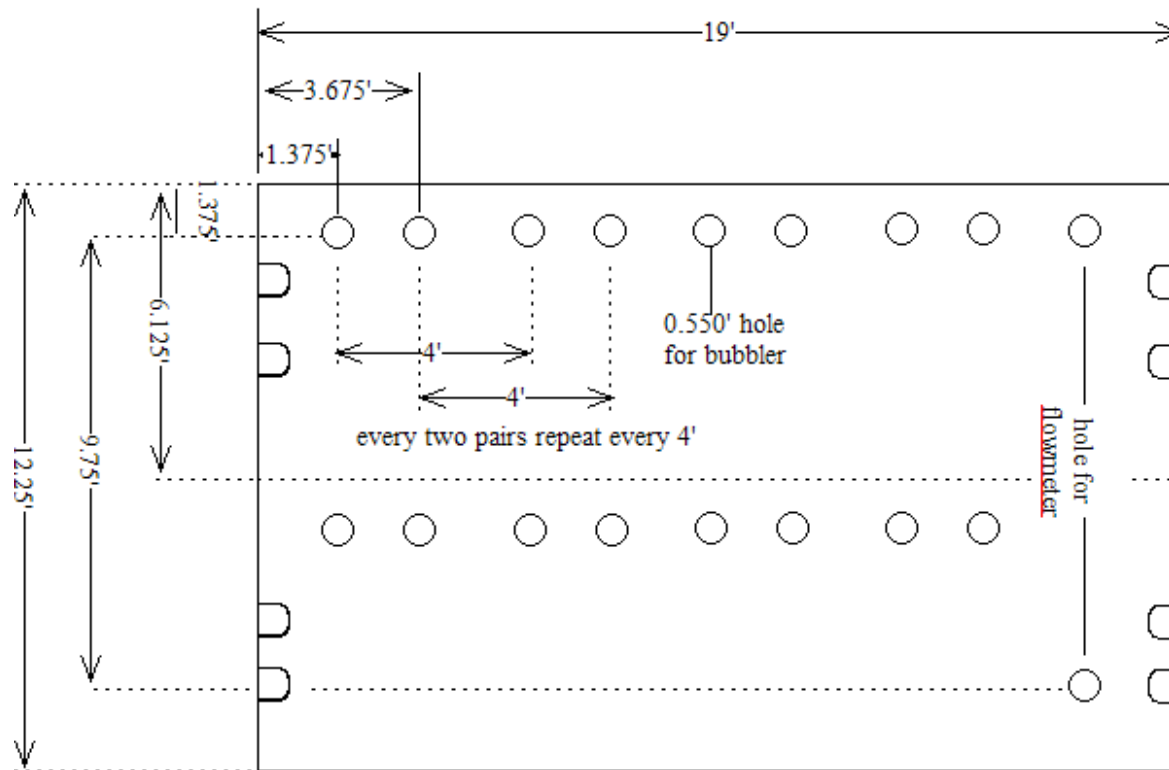
Assembled Gas Panel(Front View)
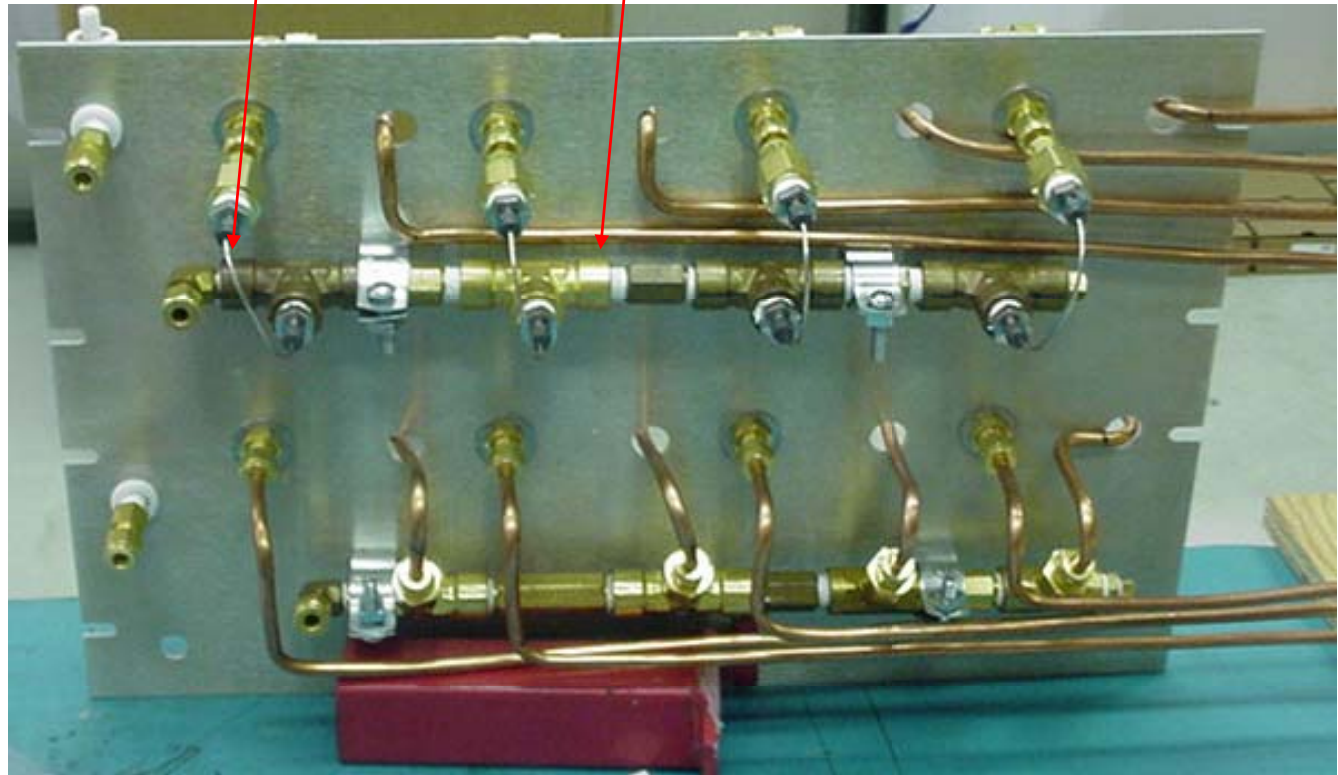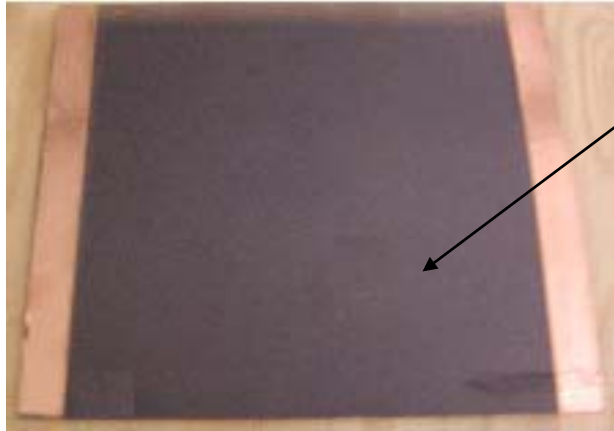
Bubbler

Flowmeter

Assembled Gas Panel(Back View)

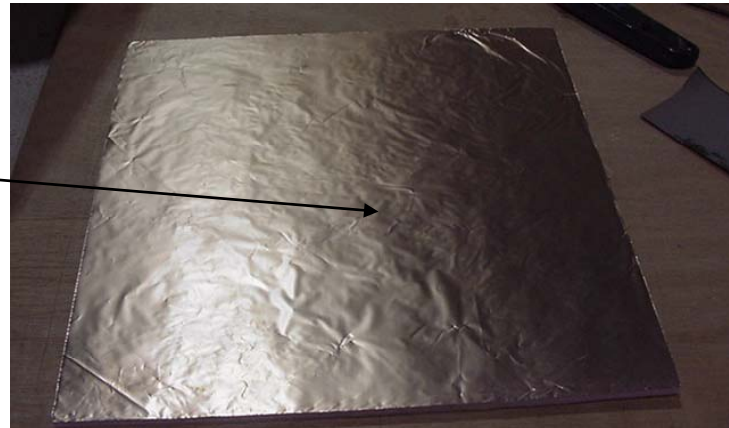Flow resistors   Manifold

Electrode and Readout Pad

Resistive layer: to apply high voltage and create an electric field inside the gas volume
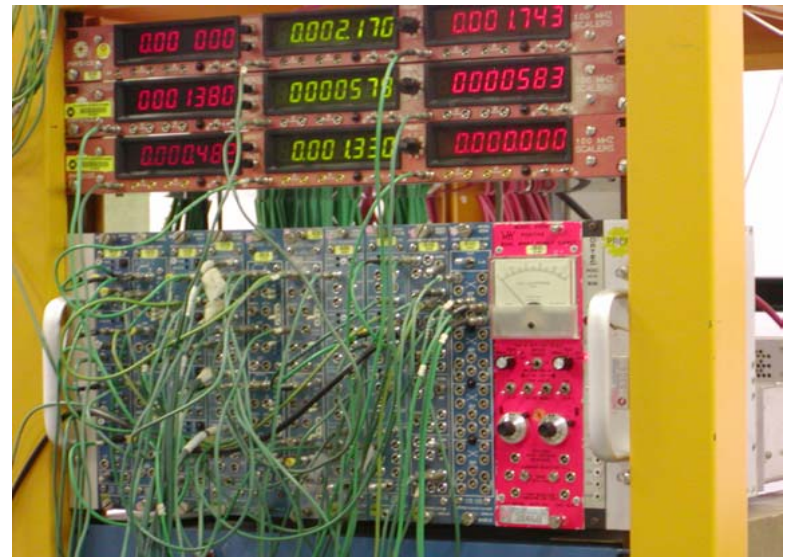
Copper foil: to pick up an induced signal

Signal Processing

- ◆ Trigger System
  - • Scintillators
  - • Discriminators
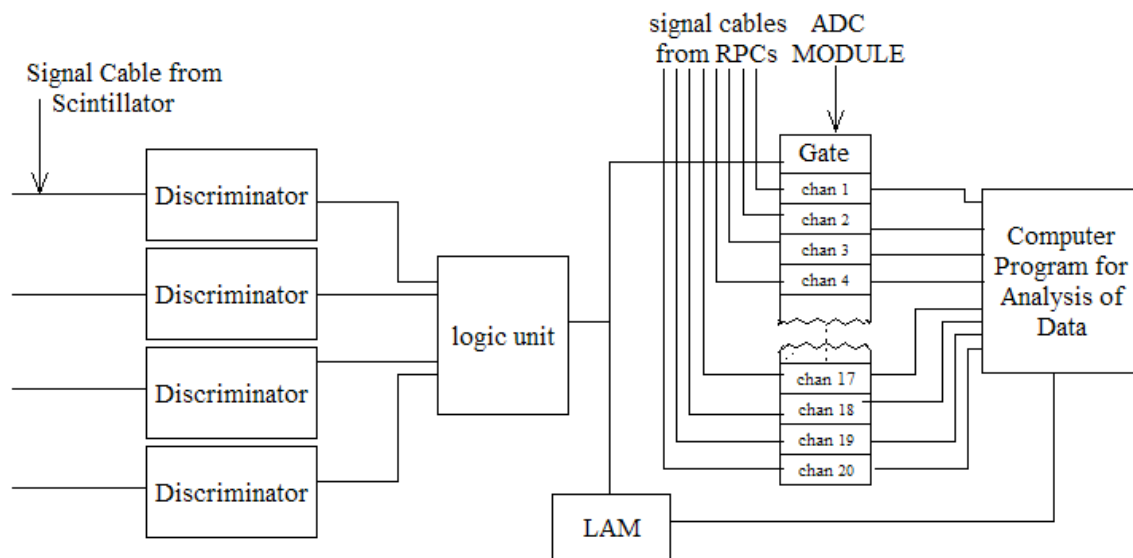 - • Logic Unit

- ◆ RPC readout
  - • Analog to Digital Converter
  - • CAMAC/PC
  - • Data Acquisition Program(FORTRAN)

Electronics Layout

- Discriminator: Gives a standard logic pulse, when input is above a set threshold
- Logic Unit: Boolean logic AND gate
- ADC: Converts analog signals to binary format
- Gate: Opens ADC channels for signal integration

Data Acquisition Configuration File

```
LAM_SLOT = 12;

LAM SELECT = F:16 C:[CRATE1] N:[LAM_SLOT] E:1 A:0 DI:1;
LAM ENABLE = F:28 C:[CRATE1] N:[LAM_SLOT] E:1 A:0;
LAM POLL = F:8 C:[CRATE1] N:[LAM_SLOT] T:0 E:1 A:0;
LAM READ = F:1 C:[CRATE1] N:[LAM_SLOT] T:1 E:1 A:2;

ADC_SLOT = 16;
ADC_CHAN0 = 0;
ADC_CHAN1 = 1;
ADC_CHAN2 = 2;
ADC_CHAN3 = 3;
ADC_CHAN4 = 4;
ADC_CHAN5 = 5;
ADC_CHAN6 = 6;
ADC_CHAN7 = 7;
ADC_CHAN8 = 8;
ADC_CHAN9 = 9;
ADC_CHAN10 =10;
ADC_CHAN11 = 11;

ADC_SLOT2 = 17;
ADC_CHAN0 = 0;
ADC_CHAN1 = 1;
ADC_CHAN2 = 2;
ADC_CHAN3 = 3;
ADC_CHAN4 = 4;
ADC_CHAN5 = 5;
ADC_CHAN6 = 6;
ADC_CHAN7 = 7;
```

- Defines a hardware configuration
- Defines a sequence of data acquisition actions

```
ADC CLEAR = F:9 C:[CRATE1] N:[ADC_SLOT] A:0 E:0 ;
ADC CLEAR = F:9 C:[CRATE1] N:[ADC_SLOT2] A:0 E:0 ;
ADC READ0 = F:0 C:[CRATE1] N:[ADC_SLOT] A:[ADC_CHAN0] E:0 DO:2 ;
ADC READ1 = F:0 C:[CRATE1] N:[ADC_SLOT] A:[ADC_CHAN1] E:0 DO:2 ;
ADC READ2 = F:0 C:[CRATE1] N:[ADC_SLOT] A:[ADC_CHAN2] E:0 DO:2 ;
ADC READ3 = F:0 C:[CRATE1] N:[ADC_SLOT] A:[ADC_CHAN3] E:0 DO:2 ;
ADC READ4 = F:0 C:[CRATE1] N:[ADC_SLOT] A:[ADC_CHAN4] E:0 DO:2 ;
```

Status

- Rack assembled
- Trigger counters installed
- Trigger logic debugged
- Ready to take data

Acknowledgements:

- Adam Para

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- Dr Davenport

- SIST committee
- ALMIGHTY GOD